A Grass Use Intensity index to be used across regions and grassland managements

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Abstract
The widely used concept of intensity of grassland management can be defined according to the fertilization level and defoliation frequency for mown meadows or to the stocking rate for pastures. Many questions arise for comparing situations over a large gradient of pedo-climatic conditions, or grazing, mowing and mixed grass utilizations. We therefore propose an index of intensity of grassland management, combining grazing and mowing, and considering regional differences in biomass productivity. A model predicting the percentage of grass eaten by the animals as a function of the stocking rate was developed based on field measurements. The index can sum this percentage of grass defoliated by grazing to that defoliated by cutting, considering that one cut defoliates 100% of the vegetation. Regional differences in biomass productivity are taken into account by dividing the sum of defoliations by the biomass productivity of grassland at the regional level, which is estimated from remote sensing images. This index could be used to roughly estimate management intensity when field measurements are not available and a large range of situations have to be compared.

Keywords: mixed grassland, number of cuts, remote sensing, stocking rate

Introduction

Intensity of grassland management is a key parameter for assessing the effects of agriculture on grassland biodiversity. Difficulties arise when it has to be quantified over a broad range of grassland types. First, comparing mown and grazed plots or estimating the intensity of grassland management when plots are alternatively mown and grazed require estimating the proportion of standing biomass removed by the grazing events (Lienin and Kleyer, 2012). However, this proportion is rarely known. Second, the effects of the number of defoliations on grassland vegetation depend on the length of vegetation period and of other abiotic factors influencing plant growth. Quantifying management intensity in different regions therefore requires accounting for differences in the potential of biomass production across regions. Herzog *et al.* (2006) proposed to normalize the mowing and grazing intensity by the maximum of these two intensities at the regional scale. This approach is very sensitive to the determination of these maxima and thus to definition of regions and sampling effort. Our aim is here to propose a methodology for calculating an index of intensity of grass use that could be used over a large gradient of pedo-climatic conditions and plot utilization. We use the term 'Grass Use Intensity index' (*GUI*) and not 'intensity of grassland management' because the level of fertilization is not aggregated to the frequency of defoliation in the proposed index.

Materials and methods

The percentage of vegetal cover defoliated (*%D*) at each mowing or grazing cycle is first estimated to calculate a defoliation index. It is considered that 100% of the vegetation is defoliated at each mowing event. For grazing, *%D* was estimated from the stocking rate based

on sward height measurements in a field experiment comparing the effects of different grazing intensities in France, UK and Germany (Dumont *et al.*, 2007). At the French site, the percentage of grazed patches was also recorded, which showed that the percentage of vegetation below 12 cm would be a good indicator of the percentage of grazed grass (data not shown). This percentage was thus used to determine the effect of the stocking rate (LU days ha^{-1}) on *%D* by grazing in the three sites. The defoliation index was then obtained by summing the percentage of defoliation in successive plot utilizations along the grazing season. We propose to use the Normalized Differenced Vegetation Index (NDVI) from remote sensing images to estimate potential grass production (P_{pot}) at each site (Paruelo *et al.*, 1997). NDVI values were obtained from MODIS satellites images (250 m·250 m pixel, one image every 16 days) and were filtered using the protocol of Taugourdeau *et al.* (2010). A model to estimate grass production from the yearly dynamic of NDVI was constructed using production data from 217 grasslands in France and Switzerland. To facilitate the interpretation of the absolute values of the *GUI*, the index could be scaled with a reference yield and corresponding number of cuts for an intensive utilisation system, for instance 5 cuts (Σ *%D* = 500) for a production of 12 t DM ha^{-1} yr^{-1}. The *GUI* is thus calculated as:

$$GUI = \frac{\sum \%D}{P_{pot}}\left(\frac{12}{500}100\right)$$

Results and discussion

The relationship between the number of LU days ha^{-1} during one grazing cycle and the percentage of vegetation below 12 cm was found to be: *%12cm* = 16.28*ln* (LU days ha^{-1}) – 10.3 (R^2 = 0.70; Figure 1) for the less productive site in France (F), and *%12cm* = 20.60*ln* (LU days ha^{-1}) – 44.6 (R^2 = 0.69) for the more productive sites in Germany (G) and the UK. The difference between sites is probably due to the grazing behaviour of cattle that were shown to increase their selectivity for short vegetative regrowths in the most productive grasslands (Dumont *et al.*, 2007). This could explain the lower percentage of plot cover that was considered as being grazed for a given stocking rate in G and in the UK compared with F.

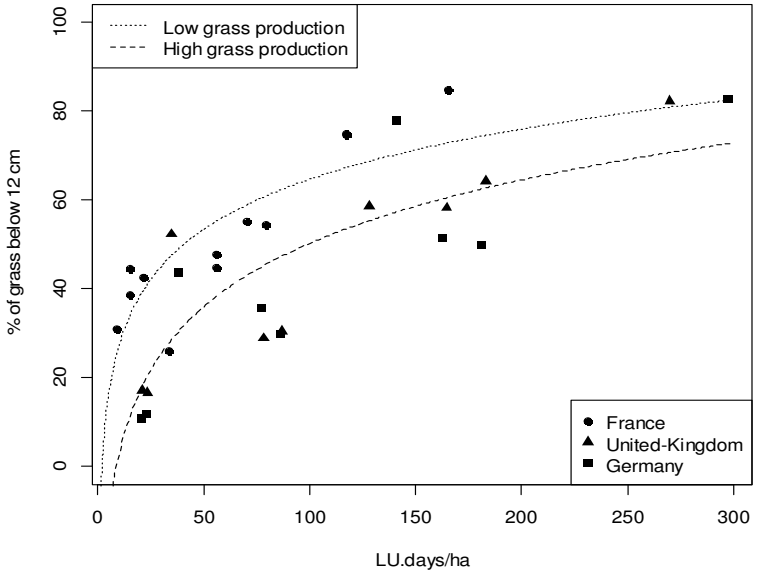

Figure1. Relationships between stocking rate and percentage of cover below 12 cm for each grazing cycle based on three sites in F: France, U: United-Kingdom and G: Germany.

Productivity of the 217 grasslands with yield data was best predicted from the dynamic of the NDVI of the pixels corresponding to the locations of the grasslands by the equation: $P_{pot} = 11.9NDVI_{feb} + 6.9NDVI_{sep} - 14NDVI_{nov} + 4.8$ ($R^2 = 0.38$). Examples of *GUI* calculated for some scenarios using the above proposed equations are given in Table 1. For a grassland situated at a location with a P_{pot} of 7.2 t DM ha^{-1} yr^{-1} (e.g. upland areas), 3 cuts per year correspond to a *GUI* of 100, while for the same number of cuts at a location with a P_{pot} of 12 t DM ha^{-1} yr^{-1} (lowland) the *GUI* would be of 60. Grazing 770 LU days (which corresponds to a grass consumption of 10 t DM) in 7 grazing cycles at the location with P_{pot} =12, yield a *GUI* of 73, although this corresponds to an intensive grazing system. The lower *GUI* calculated for intensive grazing than for intensive cutting is due to the fact that the percentage of cover defoliated by grazing animals never reaches 100% even in the most intensive systems.

Table 1. Calculated Index of Grass Use Intensity (*GUI*) for locations with different potential of production (P_{pot}) under different agricultural management.

P_{pot} (t DM ha^{-1})	Cuts	LU days	Graz. cycles	Σ%*D*	*GUI*
12.0	5			500	100
12.0	3			300	60
12.0		770	7	366	73
12.0	3	330	3	457	91
7.2	3			300	100
7.2		440	4	265	88

This paper proposes a methodology for calculating an index that could quantify grass use intensity over a large gradient of pedo-climatic conditions and for different types of utilization. Combining information from remote sensing images to estimate the potential grass production across regions with an empirical model to estimate the proportion of plot cover defoliated during grazing events allows such comparisons. The relationship between stocking rate and percentage of defoliated cover as well as the estimation of the potential grass production from NDVI are based on a small number of data, and will have to be validated before the proposed *GUI* can be widely used.

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